Treatment of Lead-Bearing Residues in a Rotary Kiln

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June 1989

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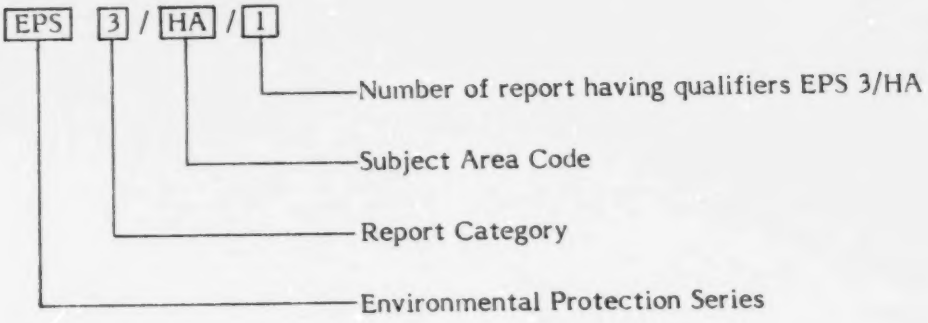

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TREATMENT OF LEAD-BEARING RESIDUES IN A ROTARY KILN

by

NOVA Pb Inc.
Ville Ste-Catherine, Québec

for the

Technology Development and Technical Services Branch
Environmental Protection
Conservation and Protection
Environment Canada

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Readers who wish to comment on the contents of this report should address their comments to:

S.A. Ross
Technology Development
and Technical Services Branch
Conservation and Protection
Environment Canada
Ottawa, Ontario
K1A 0H3

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ABSTRACT

Between January and March 1988, 711 775 kg of lead-bearing residue from Heubach Inc., the largest manufacturer of inorganic or organic pigments in the United States, was processed by NOVA Pb Inc.

This report describes the smelting process, using the rotary kiln as the smelting technology together with three additives, soda ash, coke, and iron; the product; and environmental, economic, and energy-saving benefits as they relate to the treatment of the Heubach material and similar lead-bearing residues.

RÉSUMÉ

Entre janvier et mars 1988, NOVA Pb Inc. a recyclé 711 775 kg de résidus plombifères provenant de Heubach Inc., le plus grand fabricant de pigments minéraux et organiques aux États-Unis.

Ce rapport décrit le procédé utilisé par NOVA pour le recyclage de tels résidus: fusion dans un four rotatif avec du carbonate de sodium, du coke et du fer comme additifs. Il décrit aussi la décomposition de la charge et les avantages environnementaux, économiques et énergétiques d'un tel recyclage.

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Preparation of this report and the entire Heubach project would not have been possible without the professionalism and commitment displayed by all levels of NOVA's management. In particular, the contribution of Dimitrie Hillard and Bryan Bennett is especially noteworthy. The support of Environment Canada during both phases of this project is also gratefully acknowledged.

1 INTRODUCTION AND OVERVIEW

1.1 Background

1.1.1 Phase I. During early 1983, discussions began between Noranda and NOVA (formerly Preussag Metal Inc.) to process lead-bearing dust from the Noranda Horne smelter located in Noranda, Quebec. Based upon the results of a pilot project that took place in the Preussag AG research facilities in Oker, West Germany, during 1983 and a plant-scale trial that took place in Montreal during February and March 1985, NOVA and Noranda signed a full-scale dust-tolling agreement in October 1985.

The objective of the agreement was to process both reactor and converter dust from the Horne smelter and to supply sufficient data to form the basis of a long-term dust-processing agreement between NOVA Pb Inc. and Noranda.

Phase I of the project, which involved 2100 tonnes (t), or approximately one half of the 5000 t originally projected, was completed in May 1986. The final report for Phase I was completed in February 1987. This report is available in the EP manuscript series from Environment Canada.

During April 1987, it became evident that Noranda wanted to discontinue the dust processing. The basis of this decision by Noranda was not completely clear at the time. However, it now appears that Noranda is in the process of building two rotary kilns in their Belledune lead/zinc plant (Brunswick Mining and Smelting). This rotary-kiln technology reportedly will process approximately 15 000 to 20 000 t of lead-bearing dust that is generated annually at the Horne smelter.

Therefore, it is reasonable to assume that the NOVA Pb Inc. dust trial was successful based on the fact that Noranda was sufficiently impressed with rotary-kiln technology and its ability to process lead-bearing dust that they can now rationalize their own facility dedicated to this application.

1.1.2 Phase II. As NOVA was also impressed with the flexibility of the rotary kiln and its ability to process other lead-bearing materials, the decision was made to continue the project using a lead-bearing residue from another industrial source.

Heubach Inc., located in Newark, New Jersey, is the largest manufacturer of inorganic and organic pigments in the United States, and part of their production includes lead-based pigments and chemicals. The firm is currently privately owned by West German interests; however, it was acquired from E.I. Du Pont during 1984. The lead-based products produced, mainly lead carbonate and lead chromate, are usually sold to the

paint industry, the printing industry (to manufacture ink), and the plastics and fabrics industries. Lead chromate is the main pigment used in manufacturing most yellows or oranges.

Residue is generated during the process of cleaning the equipment between batches, partially explaining the high water content, and is also generated as a result of excess or rejected material. The Heubach lead-bearing residue was chosen as the appropriate material for the project based upon the (a) quantity available, approximately 1000 t/yr on an ongoing basis; (b) composition of the material, a lead and sulphur content somewhat comparable to the Noranda dust; and (c) location and familiarity with the firm, Heubach Inc. is currently a client of NOVA Pb Inc. located within an acceptable distance from NOVA's Montreal plant.

Thus, between January 27 and March 17, 1988, 711 775 kg of material was received by NOVA. Processing began in April and involved material shredding, smelting in conjunction with regular NOVA lead sulphate, and refining to high purity soft lead.

The purpose of this report is to summarize the project and to identify key points related to the treatment of Heubach dust or similar dusts for future projects.

1.2 Preparation for the Heubach Trial

In October 1986, the governments of Canada and the United States signed an agreement regulating the transboundary movement of hazardous waste (as defined by either country). Because the Heubach lead-bearing residue was defined as hazardous waste by the New Jersey Environmental Protection Agency, the procedures outlined in the agreement were followed prior to shipping the material to Canada.

Prior to approving the importation of the Heubach material, Environment Canada asked for and received formal approval from the Quebec Department of the Environment to process the material at NOVA Pb Inc.

1.3 NOVA Plant and Equipment

The NOVA Pb Inc. plant is located in the industrial park of Ville Ste-Catherine, Quebec, covering an area of approximately 209 000 m^2. The plant is serviced by Highway 132, CP Rail, and the St. Lawrence Seaway.

The plant, built in 1979/1980, has an estimated current replacement cost of approximately $65 million. Almost half of the capital investment is environmentally related. The facilities are state of the art in terms of air and water closed-loop circuits. The special design of a long rotary kiln and the use of soda ash ensure effective capture of sulphur emissions.

In terms of capacity, NOVA Pb Inc. is Canada's largest secondary-lead facility, with a smelting capacity of 60 000 t of bullion per year and a refinery capacity rated at 120 000 t/yr. Current operations are at the 24 000 to 30 000 t commercial Pb level, placing NOVA Pb Inc. behind Cominco and Noranda in terms of refined-lead production in Canada.

In preparation for storing the raw material prior to processing, NOVA spent approximately $65 000 to enlarge and improve the storage pads upon which the drums containing the raw material would rest. This also included pad preparation that would ensure correct drainage into the NOVA water-treatment plant in the event of an accident or spillage. The main piece of equipment NOVA required to process the Heubach material, which was not required during the Noranda project, was a drum shredder. The drum shredder was purchased from Shred-Pak, located in Cambridge, Ontario, at a cost of almost $120 000 when installed. The drum shredder was essential to eliminate the need to empty the drums manually, which also improved productivity and health and safety conditions, and to facilitate recycling the drums because they could not be adequately cleaned for reuse. Because the kiln requires the addition of iron, the shredded steel drum shells also provided a source of iron.

1.4 The Smelting Process

Smelting of various lead-bearing materials is accomplished using the rotary kiln as the smelting technology together with various additives, such as soda ash, coke, and iron.

1.4.1 Raw Material Handling. Following shredding, all materials to be fed into the kiln are stockpiled prior to being batched or fed.

All materials are then loaded onto a belt system, which conveys them to the gravimetric system situated at the upper end of the kiln. Feed mix is blended with recirculating dust at this point prior to entry into the kiln.

1.4.2 Smelting. The rotary kiln is 40 m long and 2.9 m in diameter. It is heated at the exit end by an Eclipse burner with a capacity of 54.32 GJ/h (51 600 000 BTU/h). All materials are fed gravimetrically into the rotary kiln, with operating temperatures reaching 1100°C. By interrupting the rotation of the kiln, the liquid lead is tapped out, at taphole locations, into covered launders flowing into 60-ton holding kettles. Slag overflows the cone-shaped lip at the hot end of the kiln into 1-ton slag pots, which are cooled and dumped.

Depending upon the density and metal content of the feed materials, the kiln can attain daily production rates in excess of 150 t of lead per day.

1.4.3 Air-pollution Control. Kiln gases are passed through two baghouses, the reaction gases being handled in a 630-bag unit with a capacity of 80 000 m^3/h at 140°C. Tapping gases are handled in a 540-bag unit with a capacity of 80 000 m^3/h at 100°C. The system is also equipped with four air-to-air cooling towers capable of maintaining constant temperatures at the inlet to the baghouses. Captured dust is recirculated back to the kiln-feed system.

1.4.4 Additives. In terms of the chemistry of smelting lead-bearing residues, the following primary reactions take place in the kiln.

(a) Soda ash is introduced to capture the sulphur in the slag, thereby preventing the emission of sulphur dioxide.

$$PbSO_4 + Na_2CO_3 \longrightarrow PbCO_3 + Na_2SO_4$$
$$PbCO_3 \longrightarrow PbO + CO_2$$
$$PbO + O \longrightarrow PbO_2$$

Cast iron is also introduced to capture the sulphur in the slag.

$$PbS + Fe \longrightarrow Pb + FeS$$

(b) Coke is introduced as a reducing agent and a source of energy.

$$PbSO_4 + 2C \longrightarrow PbS + 2CO_2$$
$$PbO_2 + C \longrightarrow Pb + CO_2$$
$$PbO + C \longrightarrow Pb + CO$$

1.4.5 Equipment. The equipment used to run the Heubach tests can be categorized into the mixing and proportioning system (Appendix A, Figure A-1), the rotary kiln (Appendix A, Figure A-2), and the antipollution system (Appendix A, Figure A-3). Appendix Table A-1 provides information on the sampling points. Because of the special features of the Heubach dust (i.e., high humidity and very sticky), it required preparation of the kiln feed in a separate building (Building 1) and thorough mixing of all raw materials and additives. The various components of the kiln feed were proportioned by means of automatic scales installed on the front-end loaders.

During the tests, NOVA's in-house proportioning, measurement, and adjustment systems were used and were considered to be sufficiently accurate and reliable to control process parameters, such as raw materials, additives, heat consumption, temperature, and secondary air.

2 FEED MATERIAL DESCRIPTION

To achieve complete control of the process and a better evaluation of the results, it was decided to feed the kiln with a mix in which the "Heubach dust" would represent 6 to 10% of the total raw material on a wet basis. (The average was 8%.) Specifically, the blending of Heubach and regular NOVA feed was designed to allow for a metallurgical comparison and evaluation with a known standard.

2.1 Heubach Dust

The main components of Heubach dust include lead sulphate, lead chromate, and lead carbonate. The average composition of the dust was as follows:

Element	Dry basis (%)	Element	Dry basis (%)
Lead (Pb)	51.5	Chromium (Cr)	5.83
Antimony (Sb)	0.44	Tin (Sn)	0.0588
Copper (Cu)	0.0026	Nickel (Ni)	0.0024
Silver (Ag)	0.0034	Bismuth (Bi)	0.0145
Arsenic (As)	0.0975	Cadmium (Cd)	0.0006
Zinc (Zn)	0.0058	Tellurium (Te)	F0.0001
Iron (Fe)	0.0728	Sulphur (S)	7.2

The average moisture content of the dust was 34.1%. Particle size distribution was: +65 mesh, 1%; -65 + 100 mesh, 7.5%; -100 + 200 mesh, 40.0%; and -200 mesh, 51.5%. The apparent density of the dust was 2.35 t/m^3.

2.2 Treated Battery Lead

Treated battery lead (TBL) or lead sulphate sourced from crushing lead acid batteries had an average composition of water, 12%; lead (dry basis), 58.9%; antimony (dry basis), 1.6 to 1.8%; and sulphur (dry basis), 4 to 5%.

The apparent density fluctuated between 2.2 and 5.1 t/m^3. The increased density was a function of a mix of metallic lead in the total charge, i.e., per mix of lots B, C, D, F, and G (refer to Section 3.4.1).

2.3 Dross

During the smelting and refining process, the contaminants with a lowe density than lead float to the top of the kettle and are subsequently removed b skimming. This material is referred to as dross and is recycled back into the kiln fo further smelting.

In this case, there were two types of dross: antimonial and copper. Th antimonial dross was made up of 85% Pb and 12% Sb, and had an apparent density o 4.2 t/m^3. The copper dross consisted of 98% Pb and 1 to 2% Sb, and had an apparen density of 5.1 t/m^3.

2.4 Additives

Three additives were used in the smelting process: soda ash, iron chips, and coke.

The soda ash was of commercial grade (99.2% Na_2CO_3 (sodium carbonate)) and had an apparent density of 0.9 to 1.1 t/m^3.

The iron chips were of variable grades. The total Fe ranged from 80 to 90% and the apparent density was 2 t/m^3. Part of this additive was assumed to be the metallic drums (Heubach containers) that were shredded.

The coke was made up of 12% water, 13% ash, 79% fixed carbon, and 0.90% sulphur.

3 PROCESSING

3.1 Shipping and Handling Procedures

The Heubach lead-bearing industrial waste was shipped by Heubach in 55 U.S. gallon (208 L) metal drums (according to United States Department of Transport approved standards for this type of material). Each drum had a full open top secured with a bolted steel ring and lid. The fit between the lid and the drum was virtually airtight.

The drums were strapped onto 4 x 4 foot (1.2 x 1.2 m) heavy-duty wooden pallets and were transported in closed vans.

Each shipment consisted of 10 or 12 pallets, representing 40 to 48 drums per truckload. The net weight of a shipment was between 13.5 and 18 t. The vans were unloaded using a forklift, and the wooden pallets and drums were stored on an asphalt pad. Forty-four shipments were received between January 27 and March 17, 1988.

3.2 Preprocessing Preparation

For each lot, a composite sample was taken and analyzed (Appendix Tables B-1 and B-2).

3.3 Container Processing

After the preprocessing preparation, the containers (drums) were shredded in a drum shredder. The shredder was located close to the NOVA drainage system and water-treatment plant, which could handle the water or spillage resulting from the container processing. Because of the high moisture content of the Heubach material (34.2%; see Appendix Table B-2), control of the fluid following shredding was essential. Although none of the Heubach liquid flowed into the water-treatment plant, because it was transported to the mixing building by payloader, the potential impact on the efficiency of the water-treatment system was analyzed. It was determined that the presence of a minimal amount of lead chromate in the basin would have no impact on the normal efficiency of the flocculents and the water-treatment plant in general.

3.4 Smelting and Refining Procedures

3.4.1 Kiln Feed. As mentioned earlier, the Heubach dust was processed in conjunction with other lead-bearing material. Representative ratios between the other lead-bearing material and the Heubach dust, which were used during the tests, are presented in Table 1.

TABLE 1 RATIOS BETWEEN OTHER LEAD-BEARING MATERIAL AND HEUBACH DUST

Type of mix	Total raw material (t)	Heubach (%)	TBL (%)	Metallic Pb (%)	Cu dross (%)	Sb dross (%)
A	150	6.0	80.5	-	13.5	-
B	180	5.0	67.5	16.5	11.0	-
C	170	9.0	67.6	11.7	11.7	-
D	170	9.0	67.6	11.7	11.7	-
E	160	8.0	48.0	-	-	44.0
F	180	10.0	40.0	-	-	50.0
G	190	6.0	62.5	21.0	10.5	-
H	200	7.0	58.0	17.5	17.5	-
I	165	10.0	68.8	-	21.2	-
TOTAL	1565					

Note: The mixes listed are representative samples only, not the complete material as noted in Section 4.4.

3.4.2 Additives. The additives used for each type of mix are presented in Table 2.

TABLE 2 ADDITIVES

Type of mix	Soda ash (t)	Coke (t)	Iron (t)
A	14.5	15.0	7.5
B	14.5	14.5	7.5
C	14.5	14.5	7.5
D	14.5	16.5	7.5
E	8.5	15.5	3.0
F	8.5	16.0	3.0
G	15.0	16.0	7.0
H	16.0	17.0	8.0
I	18.0	17.0	8.0

The quantities were determined according to the required stoichiometrical balance, taking into consideration the content of S, PbO (lead monoxide), PbO_2 (lead dioxide), and $PbSO_4$ (lead sulphate). In the case of iron, the metal in the Heubach shredded drums was also taken into account.

3.4.3 Operational Parameters (during tests). The operational parameters are presented in Table 3.

TABLE 3 OPERATIONAL PARAMETERS

Operational time of the kiln (543 hours over 28 consecutive days)		80.8%
Feed rate (mixes)		13.4 t/h (approx.)
Feed rate (additives)		2.36 t/h
Feed rate (total)		15.76 t/h
Bullion production		144 t/d
Slag production		45 t/d
Stack flue gas		80 000 m^3/h
Natural gas flow rate		500 m^3/h
Additive consumption:	Soda ash	0.96 t/h
	Coke	1.03 t/h
	Iron chips	0.375 t/h
Tapping cycle		4 times/day
Kiln rotation		0.7 r/min
Average retention time		2.5 h

3.4.4 Operational Review. The feed must be prepared in advance by intimately mixing all components on the floor. To minimize the CO content in the gases (for a 500 m^3/h gas flow rate), a draft of 25 to 35% is optimum. The natural gas consumption is higher than normal, with approximately 15 to 20% of the increase being attributed to the high water content of the Heubach material. The reaction gas temperature at the kiln feed end is 280 to 320°C. Before the bag filter, the reaction gas temperature is 135 to 145°C. No rings formed in the transition zone (where phase changes occur). Some small deposits were observed, but they are not as resistant as those formed during normal operation. Wearing of the refractory lining during processing was found to be normal.

4 ENVIRONMENTAL CONSIDERATIONS

4.1 Products of Trial Program

4.1.1 Bullion. There were 4038 t of lead bullion produced during the trial program. Detailed chemical analyses are presented in Table 4.

TABLE 4 CHEMICAL ANALYSIS OF BULLION

	Sn (%)	Sb (%)	Cu (%)	Ni (%)	Fe (%)	Zn (%)	Ag (%)	As (%)	Cd (%)	S (%)	Te (%)	Bi (%)	Cr (%)
A	0.0002	1.98	0.028	0.0007	0.0002	0.0002	0.0012	0.098	0.0004	0.0016	0.0041	0.0106	0.0002
B	0.1548	1.96	0.037	0.0006	0.0011	0.0001	0.0014	0.063	0.0012	0.0023	0.0035	0.0112	0.0002
C	0.0028	1.76	0.038	0.0007	0.0009	0.0001	0.0014	0.056	0.0004	0.0032	0.0029	0.0112	0.0002
D	0.0011	1.60	0.028	0.0005	0.0008	0.0002	0.0015	0.052	0.0003	0.0150	0.0040	0.0115	0.0003
E	0.0004	1.84	0.019	0.0007	0.0008	0.0001	0.0013	0.100	0.0003	0.0021	0.0046	0.0110	0.0003
F	0.0003	1.89	0.017	0.0009	0.0006	0.0001	0.0014	0.103	0.0005	0.0036	0.0050	0.0110	0.0002
G	0.0006	1.92	0.018	0.0019	0.0006	0.0001	0.0014	0.079	0.0001	0.0022	0.0055	0.0114	0.0001
H	0.0006	1.83	0.023	0.0005	0.0007	0.0001	0.0015	0.052	0.0003	0.0150	0.0045	0.0122	0.0003
I	0.0008	2.02	0.023	0.0003	0.0014	0.0001	0.0015	0.066	0.0002	0.0012	0.0039	0.0129	0.0002
Average	0.0180	1.64	0.026	0.0008	0.0008	0.0001	0.0014	0.074	0.0004	0.0021	0.0042	0.0114	0.0003

Note: Pb = 98.12% (variability).

4.1.2 Slag. There were 1254 t of slag generated during the 28-day test. As anticipated, the ratio of slag to bullion remained relatively unchanged from normal lead-bearing material processing operations at approximately 31/32% (slag/bullion). Also, there was no apparent change in slag viscosity. Detailed chemical analyses of the slag are presented in Table 5.

Slag leachate tests were performed in accordance with procedures prescribed by Environment Canada. The results of three different tests are presented in Table 6.

4.1.3 Recycled Dust. In Table 7, the main components of the dust are presented. Again, these results are within the limits of normal operation. Fifteen tonnes of recycled dust were collected.

4.2 Lead

4.2.1 Water. The rotary kiln and the refining processes are not generating industrial wastewater; however, the NOVA water-treatment plant operates continuously, processing the surface water, rainwater, and washing water collected on-site. For April 1988, the

TABLE 5 CHEMICAL ANALYSIS OF SLAG

	Lead (%)	Antimony (%)	Calcium (%)	Sodium (%)	Iron (%)	Magnesium (%)	Sulphur (%)	Tellurium (%)	Chromium (%)
A	1.4	0.13	1.28	23.7	18.3	0.39	31.1	0.0240	1.68
B	1.5	0.09	0.52	18.6	16.2	0.06	25.5	0.0310	1.40
C	2.3	0.11	0.48	15.3	19.7	0.06	34.8	0.0330	1.60
D	2.4	0.18	0.15	16.4	19.1	0.16	26.3	0.0440	1.45
E	2.2	0.37	0.96	17.4	18.9	0.26	23.7	0.0560	1.65
F	2.9	0.32	0.75	17.2	21.0	0.19	29.7	0.0430	1.60
G	2.9	0.21	0.59	18.3	20.6	0.18	34.2	0.0300	1.60
H	1.9	0.08	1.44	12.2	19.0	0.13	26.4	-	1.65
I	1.3	0.05	0.55	16.6	21.0	0.14	36.5	-	1.50
Average	2.1	0.17	0.75	17.3	19.3	0.17	29.8	0.0290	1.565

TABLE 6 SLAG LEACHATE TEST RESULTS

Element (mg/L)	Test 1	Test 2	Test 3	Norm*
Pb	0.02	0.03	0.09	0.1
Cr	0.024	0.013	0.016	F0.02
Zn	0.04	0.05	0.06	0.1
Cd	ND	ND	ND	F0.1
Cu	0.05	0.03	0.08	1.0
Ni	0.14	0.09	0.36	1.0
As	ND	ND	ND	0.5

Note: ND, not detected.
* Quebec provincial norm.

tested water provided the following average results: Pb, 0.12 mg/L (Quebec provincial norm = 0.20 mg/L); Zn, 0.04 mg/L (Quebec provincial norm = 1.0 mg/L); SO_4 (sulphate), 8925 mg/L; and pH, 9.29.

4.2.2 Stack Emissions. Another firm has been contracted to periodically measure sulphur dioxide and particulate emissions exiting the main stack and also to conduct industrial hygiene sampling inside the plant.

TABLE 7 MAIN DUST COMPONENTS

	Pb (%)	Cr (%)	S (%)
A	74	0.021	4.5
B	75	0.019	4.2
C	71	0.021	4.3
D	74	0.016	3.8
E	70	0.019	4.9
F	71	0.019	4.3
G	76	0.021	4.1
H	79	0.013	4.5
I	70	0.012	3.9
Average	73.3	0.177	4.3

The average results during normal operation, with respect to the main stack, are presented in Table 8.

TABLE 8 STACK EMISSIONS

		Norms	
	NOVA	Federal	Provincial
Particulate matter (mg/m^3)*	5.8	46	46
Lead (percent by weight of particulate matter)	13.4	63	-

* Measured at standard temperature and pressure. Under normal kiln operating conditions, the SO_2 emitted to the atmosphere was almost nil.

4.2.3 Slag. The lead content of the slag ranged from 1.4 to 2.9%, averaging 2.1%. Leachable Pb ranged between 0.02 and 0.09 mg/L (the provincial norm provides a limit of 0.10 mg/L for Pb). The slag was shipped to an approved dump site in Delson, Quebec, approximately 10 km from the NOVA plant.

4.3 Chrome

Because chrome is not soluble in water, the particles conveyed by the surface water to the water-treatment plant are recovered in the settling basin and are reprocessed during the next kiln operation.

Chrome was not detected in the stack emissions.

Chrome conversion in the slag was calculated at approximately 98.9%. During the first phase of the project, the potential for chrome recovery did not appear favourable because of low chrome concentrations. Leachable Cr averaged 0.018 mg/L, which is less than the provincial norm of 0.02 mg/L.

4.4 Material Balance

The material balance for the trial program is presented in Tables 9 to 11.

TABLE 9 MATERIAL BALANCE

Kiln feed	
TBL (treated battery lead)	4346 t (66.8%)
Heubach dust	517 t (8.0%)
Cu dross	643 t (9.9%)
Sb dross	300 t (4.6%)
Metallics	700 t (10.7%)
Total input	6506 t
Additives	
Coke	501 t
Iron	182 t
Soda ash	467 t
Kiln products	
Bullion	4038 t
Slag	1254 t

TABLE 10 LEAD AND CHROME BALANCE, INPUT

Input	t	Pb(%)*	Pb(t)	Cr(%)*	Cr(t)
TBL	4346	51.83	2252.814	-	-
Heubach	517	33.93	175.41	3.84	19.85
Cu dross	643	98.00	630.14	-	-
Sb dross	300	85.00	255.00	-	-
Metallics	700	98.00	686.00	-	-
TOTAL	6506		3999.364		19.85

* Wet base.

TABLE 11 LEAD AND CHROME BALANCE, OUTPUT

Output	t	Pb(%)	Pb(t)	Cr(%)	Cr(t)
Bullion	4038	98.12	3962.00	0.0003	0.012
Slag	1254	2.1	26.33	1.565	19.632
Recycled dust	15	73.3	10.99	0.177	0.026
Stack	-	13.4	0.0337*	-	-
TOTAL			3999.354		19.67**

* From Section 3.4.3: 80 000 m^3/h x 24 h x 28 d = 43.4 x 10^6 m^3 flue gas; Pb content (from Section 4.2.2): 5.8 mg/m^3 x 13.4% x 43.4 x 10^6 m^3 = 33.7 kg.

** The difference of 0.180 t of Cr with respect to input/output represents the particles that were transported with the water in the settling basin of the water-treatment plant. The settling-basin products (the solids) are processed in the kiln when the basin is emptied. The 0.180 t of Cr will be recovered during the next operation in the kiln slag.

5 OPERATIONAL REVIEW

A total of 517 t of Heubach dust was fed into the kiln along with normal NOVA TBL, dross, metallics, and varying amounts of additives.

Test results indicate that the Heubach dust can be processed in NOVA's rotary kiln (using soda-ash technology) to produce lead bullion and a slag in which the chrome and sulphur conversion is approximately 98.9% for chrome and 99.5% for sulphur.

5.1 Problems/Proposed Solutions

The test was successful in confirming the metallurgical process while respecting applicable environmental regulations. To ensure that NOVA Pb can handle and treat the dust or other similar material in a safe and economical manner, the following areas should be addressed:

(a) Building 1 and annex:

- To "minimize outside circulation" of raw materials and additives, all products should be concentrated in Building 1.
- New enclosures connected to Building 1 should be built for metallics/soda ash, iron chips, coke, and dross.
- The existing space within Building 1 should be reorganized.
- A more accurate weighing system should be installed on the payloader.
- The shredder should be relocated inside Building 1.

(b) Stack-emission control: Although no problems were detected, for the continuous control of stack emissions (particulate concentrations of flue gases and SO_2), improved control equipment should be installed.

(c) Kiln process control: Although the current manual system operates effectively, for more efficient operation of the kiln, the quality of flue gases must be checked continuously. New automated instruments for CO (carbon monoxide), CO_2 (carbon dioxide), O_2 (oxygen), and CO/CO_2 should be installed, therefore, to provide completely automated process control.

Regretfully, the efficiency of the new filter-press system and drum-loading system at Heubach was not operating at anticipated levels at the beginning of its operation; thus, the moisture content of the material was extensive. The current objective is to attempt to reduce this moisture level to approximately 15 to 18%. This level should reduce the cost of treating the Heubach material significantly and improve

material handling at NOVA. At the same time, this level would be sufficiently moist to avoid a dusting problem.

6 ECONOMIC OVERVIEW

From an economic perspective, treatment of the Heubach lead-bearing residue proved relatively successful, especially when the capital cost of the new plant and equipment are not included as part of the Heubach processing costs.

In fact, since the NOVA treatment charge of $0.212 U.S. per pound ($0.5796 Cdn. per kilogram) was applied to the gross weight of all incoming material, Heubach actually paid NOVA to remove the material from its Newark, New Jersey, plant. Revenue calculations are presented in Table 12.

TABLE 12 REVENUE CALCULATIONS

Per truckload	
Average gross wet weight per load (kg)	16 177
Treatment charge (U.S. dollars per pound)	0.212
Treatment charge (Canadian dollars per kilogram)	0.5796
Average published price for lead during period (Canadian dollars per kilogram)	0.929
Average Pb content per load (% dry basis)	51.5%
Average Pb content per load (% wet basis)	33.9%
Average Pb content per load (kg)	5484

Note: Freight costs were paid by Heubach.

Revenue calculations per load payable are as follows:

Lead payment:

Pb content (kg) x Pb value (Canadian dollars per kilogram)

5484 x 0.929 = $5094.64

Deduct treatment charge:

Gross weight (kg) x treatment charge (Canadian dollars per kilogram)

16 177 x 0.5796 = $9376.19

Total payable to NOVA = $4281.55

In summary, NOVA's revenue per load was approximately $4281.55, for a total of $188 388.20 on the 44 loads represented. Total costs, including shredding, smelting, refining, slag disposal, overhead, and depreciation, were approximately $0.228 Cdn. per

kilogram, for a total of $162 288. Thus, a profit of $26 100, or 13.9% of revenue, was made.

From Heubach's perspective, there were essentially two alternatives regarding this material. The traditional approach of landfill would cost $100 U.S. per drum. (At an average of 40 drums per truck, this represents a cost of $4960 Cdn. per truck.) The second alternative, i.e., recycling, in addition to being modestly less expensive ($683 Cdn. per load or 14% less than landfill), also eliminated any potential long-term liability that could arise from landfilling with a product such as lead chromate. Freight costs for either option were to be paid by Heubach.

6.1 Energy Savings

Total energy costs to process the Heubach product were estimated to be only about $0.06/kg of the total cost of $0.228/kg. Approximately 50% of the energy was consumed in the kiln in the form of natural gas, which is used in the smelting process.

In terms of energy savings, independent studies have shown that the energy required to recycle lead, as opposed to the mining and smelting of lead-bearing ores, is significantly reduced. An extract from a Bureau International de la Récupération study indicates that lead recycling represents a 60% energy savings as compared to primary lead smelting.* The exact energy savings are difficult to quantify, however, because they are directly related to the technology and raw material utilized in individual facilities.

6.2 Other Potential Applications for NOVA's Technology

Based upon the experience and success of the Noranda and Heubach tests, NOVA is in a position to be very enthusiastic about examining the feasibility of treating other lead-bearing products. The main areas of concern when examining new materials are (a) compliance with environmental regulations in all areas; (b) the negative impact on personnel, equipment, and facilities (e.g., employee health and safety, kiln refractory lining, baghouses, etc.); and (c) the negative impact upon NOVA's normal battery-based operation. (Because of the recirculating nature of the gas and dust trail, residual elements, such as silver or bismuth, that NOVA lacks the plant and equipment required to

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* Bureau International de la Récupération, "Recycling Means Energy Savings," Recycling Today, 26(4): 74 (April, 1988).

remove could have a long-term negative impact on the quality of NOVA's regular production.)

A preliminary examination of other dusts and residues available in Canada reveals a wide variety of products and volumes. In brief, however, any firm involved in the lead industry that does not have a smelter generates lead-bearing dust and sludges that it cannot process internally.

A brief inventory of waste products available from lead facilities located in Canada is presented below.

(a) Federated Genco:

Location: Montreal, Quebec.
Product: Baghouse flue dust/sludge.

Chemistry:	Pb	17.0%
	H_2O	33.0%
	Sn	6.6%
	Cl (chlorine)	1.0%
	Sb	0.21%
	Fe	0.48%

Quantity: Approximately two to four truckloads per year.

(b) Kidd Creek:

Location: Timmins, Ontario.
Product: Lead-silver residue.

Chemistry:	Pb	30 - 38%
	H_2O	30 - 35%
	Ag	1000 - 2000 g/t
	Fe	6 - 7%
	As	2.5 - 4%

Quantity: Approximately 2500 t/yr.

(c) Hudson Bay Mining & Smelting:

Location: Flin Flon, Manitoba.
Product: Lead-silver residue.

Chemistry:		
	Pb	15%
	S	6%
	SiO_2 (silicon dioxide)	6%
	As	5.2%
	Zn	11.0%
	Cu	1.5%
	Ag	1.59 g/t
	Au (gold)	73.7 g/t
Quantity:	Undetermined.	

(d) CarterChem:

Location: Montreal, Quebec.
Product: Various lead stearates, sulphates.
Chemistry: To be determined.
Quantity: Approximately two to five truckloads per year.

Perhaps the most interesting opportunities for NOVA are the U.S. market and the incinerator fly-ash product from Montreal. Both of these options offer volumes of product in excess of 10 000 t/yr, which is significant for NOVA considering the fact that it has between 20 000 and 30 000 t/yr of excess smelting capacity. Each of these options, however, requires additional feasibility analyses and development prior to NOVA undertaking cost effective and environmentally effective processing.

In conclusion, on the basis of Phase I and Phase II of the Environment Canada project and the state-of-the-art environmental standards of closed-loop rotary kiln technology, NOVA is in an excellent position to divert lead-bearing industrial waste from the traditional disposal circuit to the recycling circuit while conforming with environmental and metallurgical practices. In the opinion of NOVA's management, a recycling or resource-recovery approach to any product, particularly lead-bearing waste, has a more positive and long-range environmental impact than the age-old standard of disposal at an approved landfill site.

Because NOVA Pb Inc. has the only long rotary kiln currently operating in North America specifically designed to process lead-bearing products, NOVA is convinced that it has the plant, equipment, and expertise to address this market requirement.

APPENDIX A
EQUIPMENT

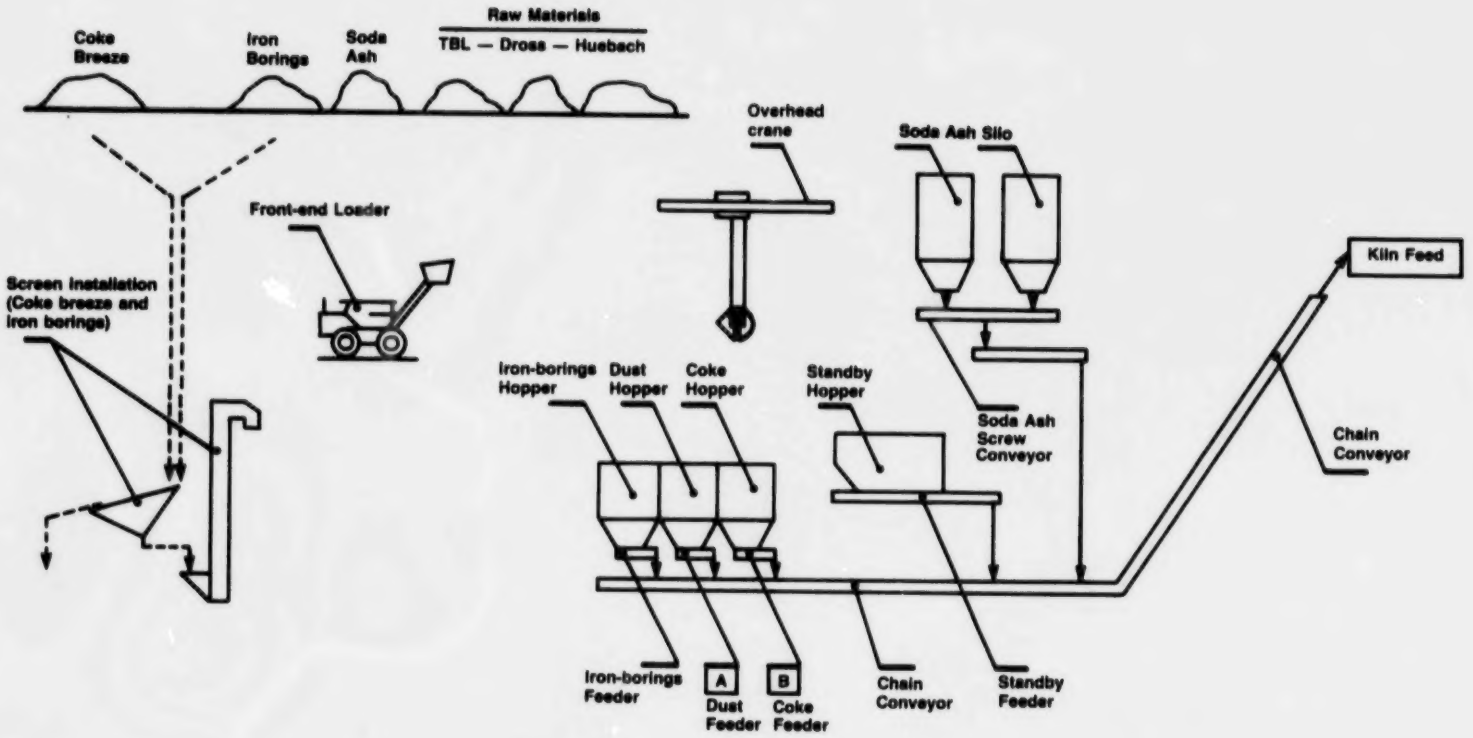

FIGURE A-1 MIXING AND PROPORTIONING SYSTEM

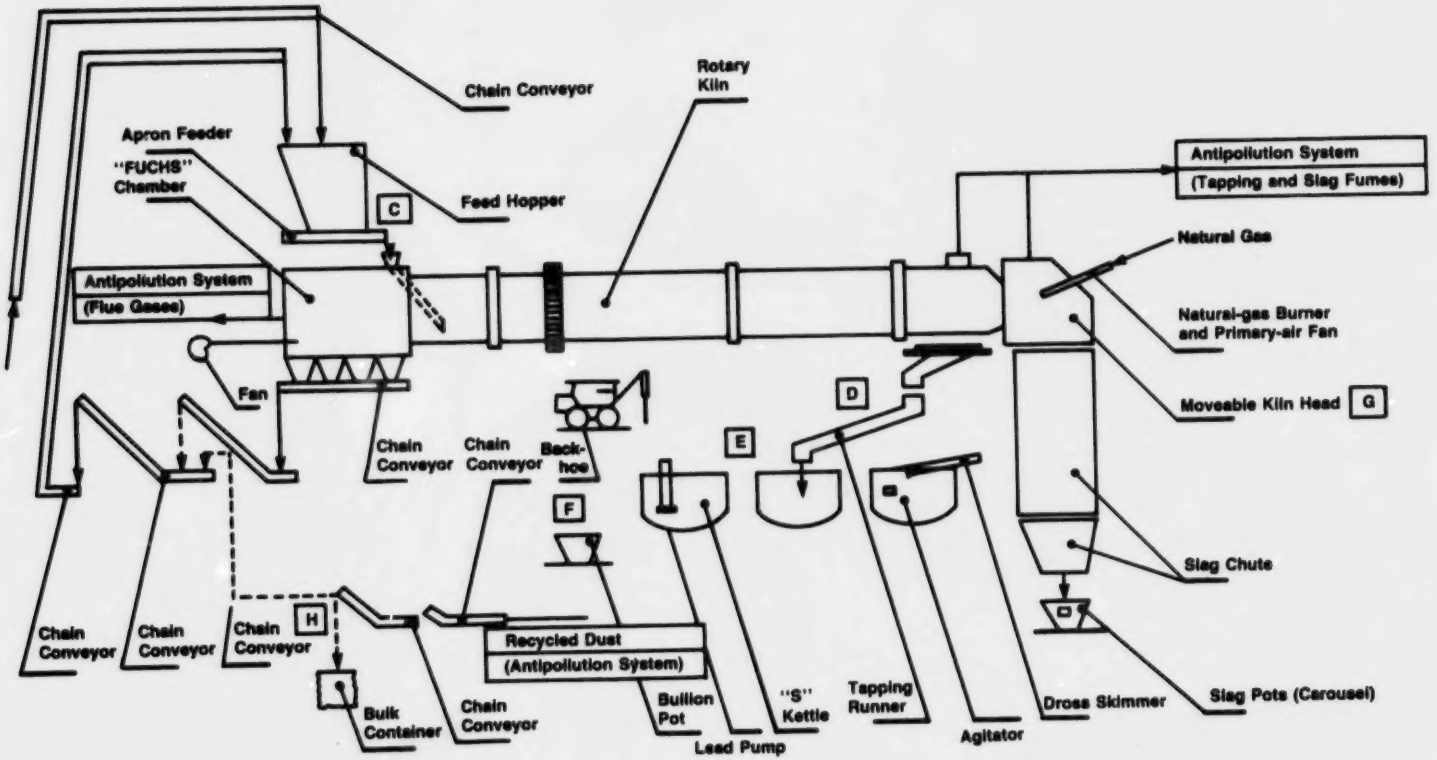

FIGURE A-2 ROTARY KILN

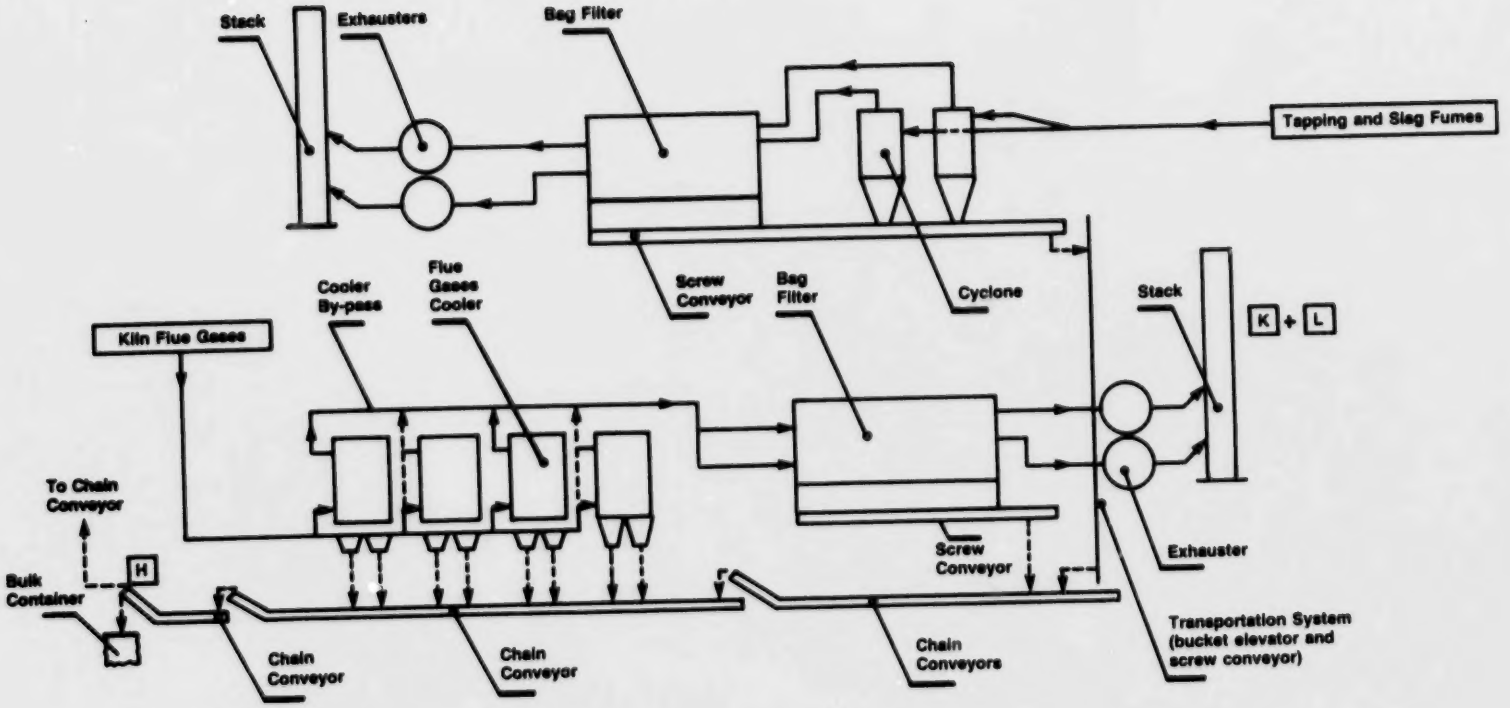

FIGURE A-3 ANTIPOLLUTION SYSTEM (flue gases and tapping and slag fumes)

TABLE A-1 SAMPLING POINTS ON FIGURES A-1 TO A-3

Item	Description	Frequency	Remarks
A	Heubach dust	Once per day	
B	Coke	Once per day	
C	Mix	Occasionally	
D	Bullion	Once per tap	Runner
E	Bullion	Once per tap	"S" kettle
G	Slag	Every 3 hours	Kiln end
H	Flue dust	Once per shift	Chain conveyor
K	SO_2	Upon request	Stack
L	Flue dust	Upon request	Stack

APPENDIX B
CHEMICAL ANALYSES

TABLE B-1 SHIPMENT SUMMARY

Load no.	Date received	Gross weight (kg)	No. of barrels/ pallets	Average moisture content (%)	Pb content (dry wt. (%))	Pb content (kg)	Sulphur content (dry wt. (%))	Chromate content (dry wt. (%))	Chromate content (kg)	Moisture content (kg)
1	Jan. 27	14 692	44/11	18.4	68.0	8152	8.84	10.10	1211	2703
2	Feb. 4	17 935	48/12	25.7	65.0	8662	0.02	9.30	1239	4609
3	Feb. 5	15 182	44/11	33.8	51.4	5166	9.25	2.49	250	5131
4	Feb. 9	13 884	44/11	30.9	49.0	4701	4.93	1.88	180	4290
5	Feb. 10	13 381	48/12	28.0	60.0	5781	6.30	4.00	386	3747
6	Feb. 11	16 656	48/12	25.0	57.0	7120	6.80	3.50	437	4164
7	Feb. 11	16 524	44/11	28.0	61.0	7257	5.00	4.27	508	4627
8	Feb. 12	15 490	44/11	31.0	44.0	4703	7.40	2.00	214	4802
9	Feb. 12	17 373	48/12	26.9	44.0	5588	2.09	1.30	165	4673
10	Feb. 15	18 008	48/12	44.3	61.0	6119	6.49	10.00	1003	7977
11	Feb. 16	15 037	44/11	25.1	45.0	5068	1.25	6.00	676	3774
12	Feb. 17	15 726	44/11	32.8	46.0	4861	7.16	5.00	528	5158
13	Feb. 18	17 273	48/12	32.3	56.4	6595	10.70	0.74	87	5579
14	Feb. 18	16 787	44/11	36.8	57.6	6111	6.65	4.20	445	6178
15	Feb. 19	15 318	44/11	38.0	47.5	4511	10.70	-	0	5821
16	Feb. 22	17 890	48/12	33.1	55.6	6654	6.30	11.10	1329	5922
17	Feb. 23	15 459	44/11	34.4	52.0	5273	10.10	-	0	5318
18	Feb. 24	19 686	48/12	43.0	43.2	4848	10.40	11.30	1268	8465
19	Feb. 25	17 078	44/11	32.9	51.9	5948	6.90	10.80	1237	5619

TABLE B-1 SHIPMENT SUMMARY (Cont'd)

Load no.	Date received	Gross weight (kg)	No. of barrels/ pallets	Average moisture content (%)	Pb content (dry wt. (%))	Pb content (kg)	Sulphur content (dry wt. (%))	Chromate content (dry wt. (%))	Chromate content (kg)	Moisture content (kg)
20	Feb. 25	16 606	44/11	27.7	47.2	5667	9.40	-	0	4600
21	Feb. 26	16 270	44/11	29.4	50.8	5835	8.06	12.00	1378	4784
22	Feb. 26	15 771	44/11	41.0	55.7	5183	6.81	13.00	1210	6466
23	Feb. 29	15 917	44/11	28.6	51.2	5819	10.40	10.00	1136	4552
24	Mar. 1	15 536	44/11	28.9	43.5	4805	12.20	1.84	203	4490
25	Mar. 1	16 461	44/11	50.4	52.5	4286	2.80	4.50	367	8296
26	Mar. 1	16 715	44/11	27.2	43.5	5293	11.50	2.85	347	4546
27	Mar. 2	16 125	44/11	31.0	51.6	5741	12.30	1.37	154	4999
28	Mar. 3	14 383	44/11	44.9	49.2	3899	4.00	2.61	207	6458
29	Mar. 3	16 316	44/11	45.2	47.5	4247	6.00	2.01	180	7375
30	Mar. 4	15 699	44/11	43.1	56.1	5011	7.05	8.00	714	6766
31	Mar. 4	13 984	44/11	44.8	57.2	4418	2.63	12.00	927	6260
32	Mar. 7	16 969	44/11	46.9	55.5	5001	9.30	5.00	450	7958
33	Mar. 7	12 252	44/11	23.9	55.3	5156	9.92	7.00	653	2928
34	Mar. 8	17 051	44/11	47.9	51.3	4557	3.24	7.00	622	8195
35	Mar. 9	16 579	44/11	57.9	60.4	4216	4.39	13.00	907	9599
36	Mar. 10	15 164	44/11	45.3	52.0	4313	1.13	13.00	1078	6869
37	Mar. 11	15 363	44/11	23.6	51.7	6068	10.30	0.33	39	3626
38	Mar. 11	15 880	44/11	19.6	52.0	6639	10.50	4.10	523	3113

TABLE B-1 SHIPMENT SUMMARY (Cont'd)

Load no.	Date received	Gross weight (kg)	No. of barrels/ pallets	Average moisture content (%)	Pb content (dry wt. (%))	Pb content (kg)	Sulphur content (dry wt. (%))	Chromate content (dry wt. (%))	Chromate content (kg)	Moisture content (kg)
39	Mar. 11	15 935	44/11	32.5	53.7	5776	6.12	1.90	205	5179
40	Mar. 14	16 325	44/11	38.2	46.0	4641	2.83	10.30	1039	6236
41	Mar. 15	18 547	44/11	44.1	57.2	5930	7.11	8.90	923	8179
42	Mar. 16	18 157	44/11	31.5	46.5	5784	9.40	2.00	249	5719
43	Mar. 16	16 914	44/11	27.6	51.6	6319	10.60	0.86	105	4668
44	Mar. 17	17 477	44/11	26.6	44.1	5657	8.50	3.00	385	4649
Total						243			25	245
Weighted Average		As % of total, wet				34.19%			3.54%	34.43%
		As % of total, dry				52.15%			5.39%	

TABLE B-2 CHEMICAL ANALYSES

Load no.	Gross weight (kg)	Cr (%)	H_2O (%)	Pb (%)	Sb (%)	Sn (%)	Cu (%)	Ni (%)	Ag (%)	Bi (%)	As (%)	Cd (%)	Zn (%)	Te (%)	Fe (%)	S (%)
1	14 692	10.10	8.4	68.0	0.0640	0.0001	0.0028	0.0016	0.0004	0.0020	0.0001	0.0028	0.0020	0.0001	0.0070	8.84
2	17 935	9.30	25.7	65.0	0.0600	0.0020	0.0040	0.0024	0.0026	0.0062	0.0040	0.0014	0.0020	0.0001	0.0220	0.02
3	15 182	2.50	33.8	51.4	0.0360	-	0.0020	0.0028	0.0096	0.0100	-	0.0002	0.0038	0.0001	0.0160	9.25
4	13 884	1.90	30.9	49.0	0.1300	-	0.0020	0.0022	0.0072	0.0100	-	0.0002	0.0024	0.0001	0.0120	4.93
5	13 381	4.00	25.0	60.0	0.0410	-	0.0020	0.0009	0.0035	0.0110	-	0.0002	0.0011	0.0001	0.0200	6.30
6	16 656	3.50	25.0	57.0	0.0510	-	0.0020	0.0021	0.0010	0.0083	-	0.0002	0.0050	0.0001	0.0130	6.80
7	16 524	4.27	28.0	61.0	0.0910	-	0.0018	0.0018	0.0002	0.0100	-	0.0002	0.0015	0.0001	0.0160	5.00
8	15 490	2.00	31.0	44.0	0.0340	-	0.0020	0.0010	0.0038	0.0120	-	0.0002	0.0012	0.0001	0.0200	7.40
9	17 373	13.00	26.9	44.0	0.0400	-	0.0020	0.0018	0.0014	0.0200	-	0.0002	0.0032	0.0001	0.0280	2.04
10	18 008	10.00	44.3	61.0	0.1000	-	0.0012	0.0026	0.0022	0.0004	-	0.0002	0.0002	0.0001	0.0180	6.49
11	15 037	6.00	25.1	45.0	3.2000	-	0.0060	0.0018	0.0120	0.0096	0.1600	-	0.0400	0.0001	0.4800	1.25
12	15 726	5.00	32.8	46.0	0.0040	-	0.0028	0.0016	0.0022	0.0016	0.2000	-	0.0028	0.0001	0.0334	7.20
13	17 273	0.74	32.3	60.0	0.0250	-	0.0018	0.0006	0.0106	0.0216	0.3000	0.0016	0.0004	0.0001	0.0320	10.70
14	16 787	4.20	36.8	61.0	0.3300	-	0.0026	0.0020	0.0140	0.0220	0.3000	0.0016	0.0014	0.0001	0.0420	6.60
15	15 318	-	75.0	47.5	0.7500	0.0026	0.0104	0.0044	0.0056	0.0148	0.0004	0.0004	0.0038	0.0001	0.2200	8.06
16	17 890	11.10	33.1	57.5	1.4500	0.0022	0.0022	0.0008	0.0024	0.0284	0.0006	0.0034	0.0042	0.0001	0.3400	10.70
17	15 459	-	14.4	52.0	0.2800	0.0020	0.0028	0.0004	0.0018	0.0172	0.0022	0.0034	0.0026	0.0001	0.3000	6.30
18	19 686	11.30	45.0	23.2	0.8200	0.0042	0.0016	0.0001	0.0018	0.0172	0.0022	0.0021	0.0026	0.0001	0.3000	10.00
19	17 078	10.80	20.9	51.9	0.9000	0.0029	0.0016	0.0041	0.0021	0.0066	0.0005	0.0011	0.0031	0.0001	0.2100	6.90
20	16 606	-	27.7	47.2	0.9200	0.0031	0.0021	0.0001	0.0009	0.0111	0.0010	0.0039	0.0020	0.0001	0.3000	9.40
21	16 270	12.00	29.4	50.8	1.8000	-	0.0010	0.0010	0.0006	0.0056	-	-	0.0020	0.0001	0.0652	8.06
22	15 771	13.00	41.0	55.7	0.2600	-	0.0008	0.0006	0.0012	0.0056	-	-	-	0.0001	0.0192	6.81
23	15 917	10.00	28.0	51.2	0.2000	-	0.0020	0.0004	0.0009	0.0100	-	0.0002	0.0046	0.0001	0.0738	10.40

TABLE B-2 CHEMICAL ANALYSES (Cont'd)

Load no.	Gross weight (kg)	Cr (%)	H_2O (%)	Pb (%)	Sb (%)	Sn (%)	Cu (%)	Ni (%)	Ag (%)	Bi (%)	As (%)	Cd (%)	Zn (%)	Te (%)	Fe (%)	S (%)
24	15 536	1.84	28.9	43.5	0.0420	-	0.0014	0.0108	0.0024	0.0080	0.1800	0.0002	0.0022	0.0001	0.0470	12.20
25	16 461	4.50	50.4	52.5	0.3200	-	0.0104	0.0022	0.0012	0.0160	0.2800	0.0010	0.0032	0.0001	0.3300	0.28
26	16 715	2.85	27.2	43.5	0.0350	-	0.0022	0.0060	0.0028	0.0160	0.3000	0.0002	0.0008	0.0001	0.0026	11.30
27	16 125	1.37	31.0	51.6	0.0120	-	0.0020	-	0.0010	0.0020	0.0760	0.0002	0.0018	0.0001	0.0154	12.30
28	14 383	2.61	44.9	49.2	0.6000	-	0.0012	0.0014	0.0020	0.0060	-	0.0002	0.0036	0.0001	0.0176	4.00
29	16 316	2.01	45.2	47.2	2.8400	-	0.0030	0.0016	0.0042	0.0060	-	0.0002	0.0042	0.0001	0.0722	6.00
30	15 699	8.00	43.1	56.1	0.8400	0.3000	0.0018	0.0024	0.0014	0.0050	0.0800	-	0.0008	0.0001	0.0190	7.05
31	13 984	12.00	44.7	37.2	0.2600	-	0.0422	0.0182	0.0010	0.0064	0.1000	0.0004	0.0010	0.0001	0.1800	2.63
32	16 969	5.00	46.9	55.5	0.5000	-	0.0020	0.0018	0.0020	0.0012	0.1100	0.0002	0.0036	0.0001	0.0540	9.30
33	12 252	7.00	23.9	55.3	0.2700	-	0.0012	0.0008	0.0024	0.0040	0.1200	-	0.0008	0.0001	0.0256	9.92
34	17 051	7.00	47.9	51.3	0.1000	-	0.0072	0.0024	0.0008	0.0012	0.1200	-	0.0006	0.0001	0.0514	3.24
35	16 579	13.00	57.4	60.4	0.0002	0.1000	0.0062	0.0022	0.0010	0.0088	0.1180	0.0002	0.0008	0.0001	0.0982	4.30
36	15 164	13.00	45.3	52.0	1.5000	-	0.2020	0.0050	0.0022	0.0134	0.0800	-	0.0120	0.0001	0.0780	1.13
37	15 363	0.33	23.6	51.7	0.3300	-	0.0018	0.0008	0.0020	0.0066	0.0800	0.0002	0.0014	0.0001	0.0282	10.30
38	15 880	4.10	19.6	52.0	0.1000	-	0.0016	0.0008	0.0006	0.0046	0.0040	0.0002	0.0020	0.0001	0.0252	10.50
39	15 935	1.90	32.5	53.7	0.6000	-	0.0014	0.0002	0.0036	0.0144	0.0600	0.0002	0.0006	0.0001	0.0380	6.72
40	16 325	10.30	38.2	46.0	0.0760	-	0.0026	0.0064	0.0006	0.0060	0.0600	0.0002	0.0400	0.0001	0.0260	2.83
41	18 547	8.90	44.1	57.2	0.8400	0.3000	0.0019	0.0023	0.0023	0.0003	0.0090	-	0.0006	0.0001	0.0230	7.11
42	18 157	0.86	31.5	45.6	0.1100	0.0440	0.0018	-	0.0152	0.0940	0.1200	0.0002	0.0036	0.0001	0.0180	10.80
43	16 914	2.00	27.6	51.6	0.0900	0.0320	0.0020	0.0010	0.0038	0.0260	0.1300	0.0002	0.0012	0.0001	0.0120	9.40
44	17 477	3.60	26.6	44.1	0.1400	-	0.0030	0.0044	0.0016	0.0020	0.0880	0.0004	0.0160	0.0001	0.0670	8.50
Total	711 775															
Average		5.83	34.2	51.5	0.4400	0.0588	0.0026	0.0024	0.0034	0.0145	0.0975	0.0006	0.0058	0.0001	0.0728	7.25